SORENSEN
POWER SUPPLIES

ROCKFORD INSTRUMENT LAB
MESHEIM

Instruction Manual

QSA Series

WIDE RANGE POWER SUPPLIES

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SORENSEN
POWER SUPPLIES

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instruction manual for

QSA SERIES
LOW POWER LOW VOLTAGE POWER SUPPLIES

(MODELS 5-6.4, 10-1.4, 10-2.2, and 10-3.7)

SORENSEN COMPANY

A UNIT OF RAYTHEON COMPANY

676 ISLAND POND ROAD MANCHESTER, NEW HAMPSHIRE 03103

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SECTION I

INTRODUCTION AND DESCRIPTION

1.1 INTRODUCTION:

1.2 This manual provides operation and maintenance instructions for the Models QSA 5-6.4, 10-1.4, 10-2.2, and 10-3.7 voltage-regulated power supplies, manufactured by the Sorensen Company.

1.3 The manual is divided into six sections. Section I contains a description of the units, as well as unit characteristic curves and a tabular listing of complete unit specifications. Details on initial inspections and checkout procedures are given in Section II. Operating instructions, including methods for adapting units to various applications, comprise Section III. Sections IV and V provide the principles of operation and maintenance procedures, respectively. A replacement parts list forms Section VI.

1.4 DESCRIPTION:

1.5 The units provide a highly regulated (voltage) dc output and are designed to accept any of three separate, single-phase ac inputs. (For complete unit specifications, refer to Table 1-1.) They also offer extremely fast recovery times as well as characteristically low output impedances.

1.6 A wide selection of mounting positions is a unique feature. The units may be end, bottom or side mounted, using tapped holes in the enclosures. Finished with a black, baked-on, mar-resistant, wrinkle coating, these enclosures serve not only as protective housings but also as heatsinks. This latter feature eliminates the need for an external heatsink.

1.7 Operational features include remote sensing, programming, and series and parallel operation. In addition, each unit has either a current-limiting system or a current-foldback arrangement.

1.8 REMOTE SENSING: Provisions are incorporated in the unit for extending the output regulating point from the unit output terminals to the load. This feature, known as remote sensing, compensates for a maximum of 1.5 volts IR drop in each load line.

1.9 REMOTE PROGRAMMING: The unit is locally programmed, i.e., its output voltage is altered by rotation of the Output Adjust Control. To service those applications where it is desirable to maintain remote control over unit output, an arrangement for remote programming has been incorporated into unit design. This provision permits the introduction of a resistor (or a signal voltage) into the voltage adjust circuit to provide a precalculated output. Resistance-programming sensitivity is 100 ± 0.5 ohms/volt; sensitivity for voltage signal programming is 1 volt/volt. Refer to paragraph 3.16.

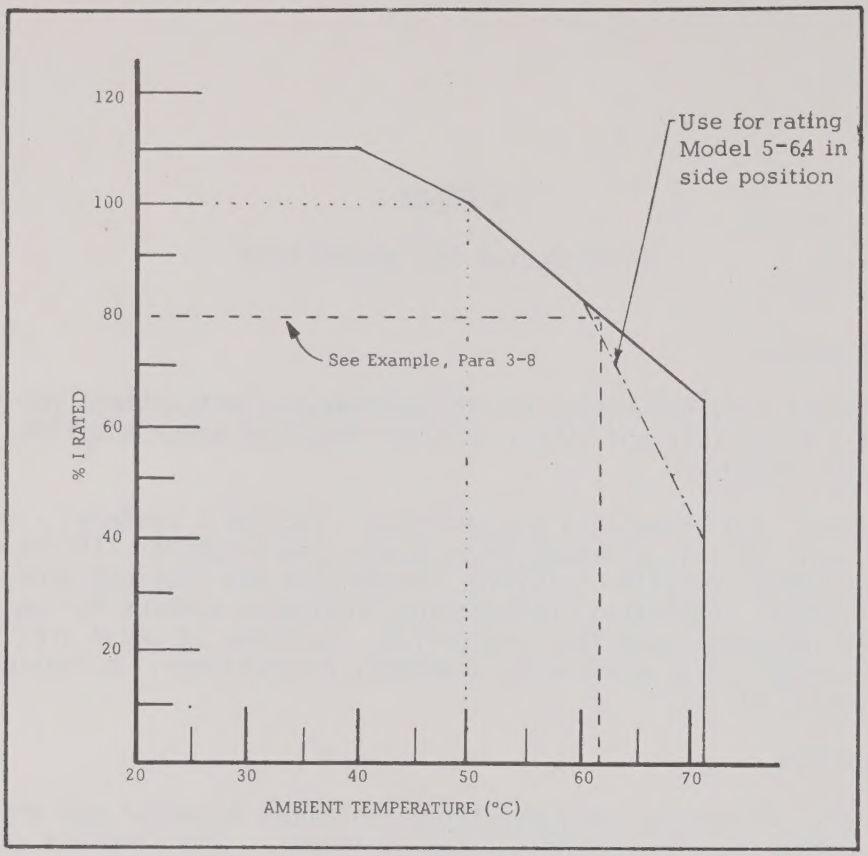


Figure 1-1 Current Derating

1.10 SERIES OPERATION: For applications requiring output voltages higher than any single QSA can supply, a number of QSA units may be connected in series. Regulation in series operation is the sum of the regulations for all units. Refer to paragraph 3.21.

1.11 PARALLEL OPERATION: Parallel operation may be used to service those applications requiring a higher output current than any single QSA can provide. Paralleling is indirect through a "master-slave" approach. The maximum number of units which may be paralleled is discussed in paragraph 3.26.

1.12 CURRENT LIMIT/FOLDBACK: The 10-volt supplied described herein contain a safety feature which prevents damage in the event of overload. As the loading increases, the current output rises to a maximum safe limit. Thereafter, the current will rise no higher, even though the load may be increased to the point of short-circuit. In the Model 5-6.4 supply, the output current actually decreases as the load is progressively increased beyond the maximum safe point.

1.13 OPTIONAL ACCESSORIES: Rack adapters (illustrated in Section 3) are offered as optional accessories to the power supplies, all designed for standard 19 inch (483 mm) racks. There are six basic rack assemblies to mount various combinations of different power supplies. The rack assemblies include provisions for slide rails and offer added versatility in that units may be mounted at the front and rear of the adapter. Racks are supplied in 3 1/2 and 5 1/4 inch (89 and 133 mm) heights and three depths; 3.62 inches (92 mm), 18 inches (457 mm), and 20 inches (508 mm).

Table 1-1 Unit Specifications

	QSA MODELS			
	5-6.4	10-1.4	10-2.2	10-3.7
Input Ratings				
Voltage ranges (Vac)	105-124/200-240/210-250			
Frequency range (Hz)	50-480			
Phase	1			
Maximum current (Aac)				
115 Vac input	1.6	0.6	0.8	1.4
230 Vac input	0.8	0.3	0.4	0.7
Power factor (typical) (1)	0.84	0.84	0.83	0.83
Efficiency (typical) (%) (1)	30.0	29.0	35.0	39.0
Output Ratings				
Voltage range (Vdc)	3-7	0-10		
Resolution (typical) (mV)	22	28		
Current range at 50°C (2) (Adc)	0-6.4	0-1.4	0-2.2	0-3.7
Current Limit or Foldback Characteristics	Fig 1-3	Fig 1-2		
Regulation (3)	±0.01%	±0.005% or ±0.2mV (4)		
Ripple Voltage (50-60 Hz)				
RMS	300 uV			
Peak-to-Peak	3 mV			
Transient Response (typical) (5)	20 us			
Temperature Coefficient	0.015%/°C	0.01%/°C or 0.5mV/°C (4)		
Output Voltage Turn-on and Turn-Off Overshoots	None			
Ambient Temperature Range	-20°C-+71°C	0-71°C		
Remote Programming				
Resistance	100 ±0.5 ohms/volt			
Voltage Signal	1 volt/volt			

(1) At nominal input and full rated output
(2) See Figure 1-1 for current derating characteristics
(3) For combined load and line
(4) Whichever is greater
(5) For a step load change NL to FL, or FL to NL, and recovery to within a ±10 mV band

Table 1-1 Unit Specifications (cont'd)

	QSA MODELS			
	5-6.4	10-1.4	10-2.2	10-3.7
Output Impedance	R + jwl			
R (u ohms) L (uH)	50 0.2	300 0.2	200 0.2	100 0.2
Stability (6)	0.025%/8 hours			
Maximum Output-Series Connected System	2 units	20 units		
Parallel Operation	See paragraph 3-26			
Remote Sensing Compensation (maximum)	1.5 volts/load lead			
Cooling	Convection			
RFI Characteristics (typical)	Meets MIL-1-6181 and MIL-1-16910			
Weight lb. (Kg)	10 (4.54)	5 (2.27)	8 (3.63)	10 (4.54)
Envelope Dimensions inches (mm)				
Width	5 1/8 (130)	3 7/8 (98)	5 1/8 (130)	5 1/8 (130)
Height	3 5/16 (84)	3 5/16 (84)	3 5/16 (84)	3 5/16 (84)
Depth	9 1/2 (241)	6 1/2 (165)	6 1/2 (165)	9 1/2 (241)

(6) 8 hours after warm-up and with constant load, line and ambient temperature

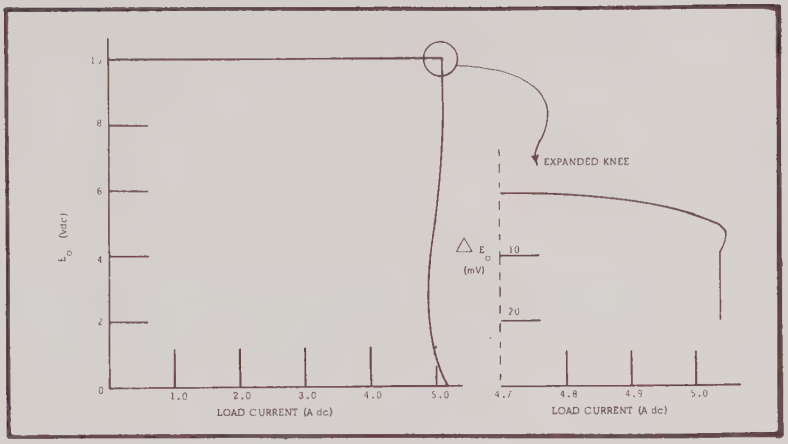


Figure 1-2 Current Limit Characteristic (typical)

There are four filler panels available:

Metered	Unmetered
PM300 3-1/2" height (89mm)	PF300 3-1/2" height
PM500 5-1/4" height (133mm)	PF500 5-1/4" height

The metered panels (which can accommodate five meters), include a voltmeter, voltage selection knob, three meter lenses and three meter filler blocks. Consult your factory representative for complete system design.

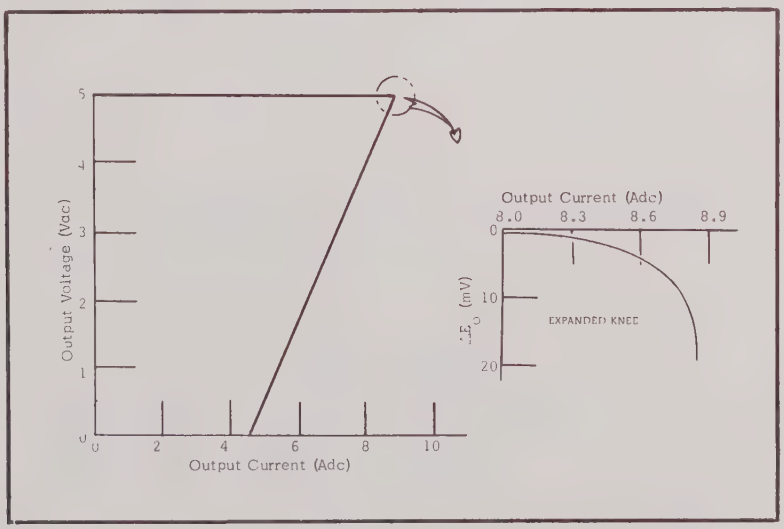


Figure 1-3 Current Foldback Characteristic - Model 5-6.4

SECTION II

PREPARATION FOR USE

2.1 GENERAL:

2.2 After unpacking, initial inspections and preliminary checkout procedures should be performed to assure that unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and of making an electrical check. If it is determined that the unit is damaged notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Dept., Sorensen Company, 676 Island Pond Road, Manchester, New Hampshire, 03103. Sorensen Company will advise the user as to what action is required to repair or replace the supply.

2.3 INSPECTION:

2.4 Check for damage incurred during shipment as follows:

a. Inspect enclosure for dents, chips, etc.

b. Check condition of external terminal board. Make certain that all screws are in place and that links are fitted over the barrier strips between the positive OUT terminal (1) and its adjacent SENSE terminal (2) and across the negative OUT terminal (4) and its adjacent SENSE terminal (3).

c. Using a slotted-drive screwdriver, rotate Output Adjust (adjust-access aperture located in nameplate) from stop-to-stop, and turn fully counterclockwise. Rotation should be smooth through a 300-degree angle.

d. Remove four screws retaining side enclosure plate, and inspect component board.

e. Remainder of enclosure may be removed by removing mounting screws and hex-head screws at nameplate end. Inspect transformer, capacitors and passing-stage transistors.

NOTE

A guide pin, located at closed end of enclosure, should be used to align enclosure and chassis when reassembling unit. Tighten cap screws to 25 lb-in.

2.5 INPUT CONNECTIONS:

2.6 If either of the two alternatives to a nominal 115-Vac input is to be used, change transformer T1 primary tap wiring as indicated in Figure 2-1. The factory-wired 115-Vac configuration is included to facilitate reconversion to this input, if such action becomes desirable at some future date. Remount enclosures following inspection or tap changing.

NOTE

Fuse the input if it is desired to protect the power transformer and rectifiers from excessive current caused by certain types of unit malfunction. Recommended fuse is Bussman Type 3AG or equivalent in the following sizes:

Input	5-6.4	10-1.4	10-2.2	10-3.7
115 Vac	2.0A	0.75A	1.0A	1.5A
220/230 Vac	1.0A	0.375A	0.5A	0.75A

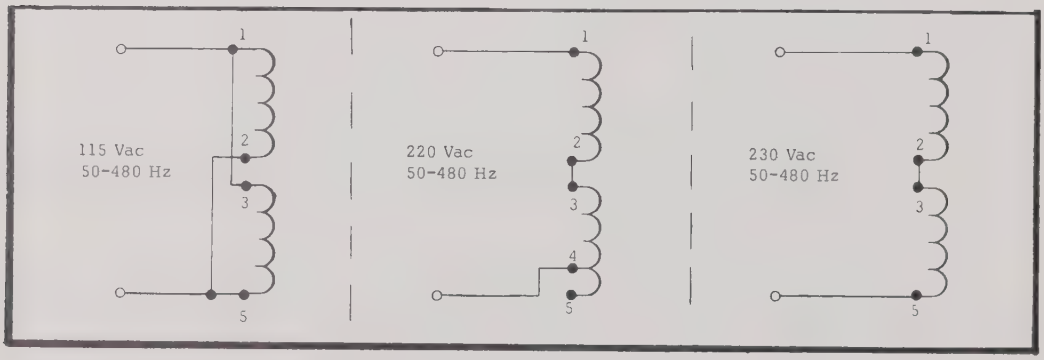


Figure 2-1 Input Connections

2.7 ELECTRICAL CHECK:

2.8 To perform an initial electrical check, proceed as follows:

a. Make certain unit is located in an area where free passage of air is unrestricted; then connect input leads to terminals 6 and 7 (IN) on unit terminal board. Use terminal 5 (GRD) for input system ground.

b. Connect a dc voltmeter across terminals 1 and 4 (OUT). Select at least a 10 V range.

c. Apply nominal input power.

d. Rotate Output Adjust from stop-to-stop. Voltmeter indicator should swing from 0 to 10 V (3-7 V if Model 5-6.4).

2.9 MOUNTING:

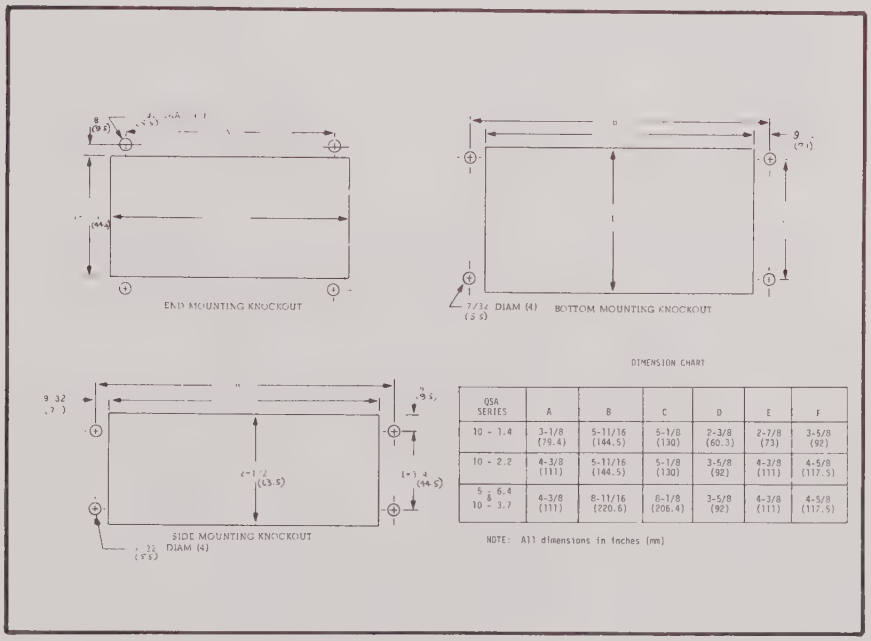
2.10 As previously mentioned, the units may be mounted in a variety of positions and locations, including a rack. Figure 2-2 illustrates the mounting-hole and knockout dimensions for end, side and bottom mounting. Use No. 8-32 screws for mounting. In determining the length of screws to be used, consider washer and mounting-surface thickness and the 3/8 in. required for maximum thread engagement. When using nameplate-end mounting, place 1/4-in. spacers over mounting holes between unit and mounting surface.

CAUTION

Knockouts are required for proper dissipation of heat generated by supply. Do not reduce knockout dimensions, nor impede natural flow of air around supply.

NOTE

If it is expected that unit will be subjected to shock or vibration during operation, do not use nameplate-end mounting.



QSA SERIES	A	B	C	D	E	F
10 - 1.4	3-1/8 (79.4)	5-11/16 (144.5)	5-1/8 (130)	2-3/8 (60.3)	2-7/8 (73)	3-5/8 (92)
10 - 2.2	4-3/8 (111)	5-11/16 (144.5)	5-1/8 (130)	3-5/8 (92)	4-3/8 (111)	4-5/8 (117.5)
5 - 6.4 10 - 3.7	4-3/8 (111)	8-11/16 (220.6)	8-1/8 (206.4)	3-5/8 (92)	4-3/8 (111)	4-5/8 (117.5)

Figure 2-2 Knockout Dimensions

If the units are to be rack mounted in the AC300 and AC500 optional adapter (figures 2-3 and 2-4), remove the adapter face plate, position the unit behind the adapter and then secure with hardware enclosed in the bag tied to the adapter handle. Fit the adapter to the rack and attach. Make the necessary input connections (paragraph 2.3), check electrically per paragraph 2.4, and adapt the unit to the desired application (section 3) before installing the face panel. If optional AC318, AC320, AC518 or AC520 rack adapters are to be used, (see Figure 2-5), your factory representative should be consulted.

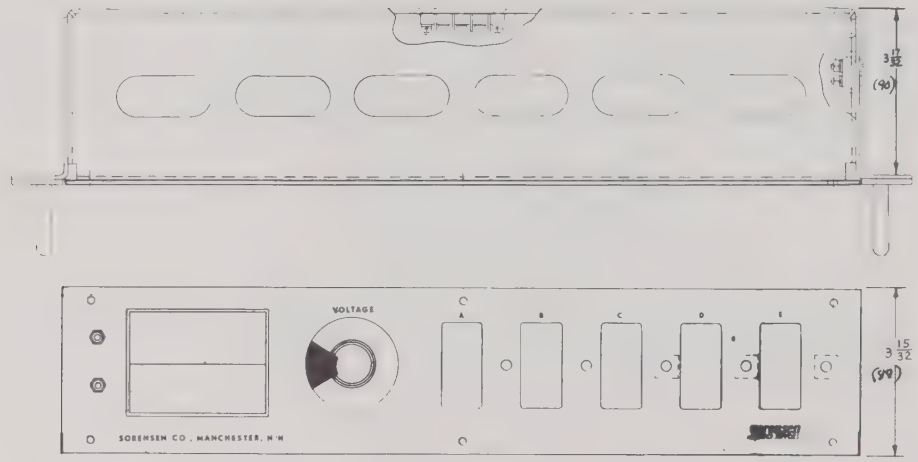


Figure 2-3 AC300 Rack Adapter (shown with metered panel)

NOTE

AC300 can accommodate three Module II or Module III units, or four Module I units.

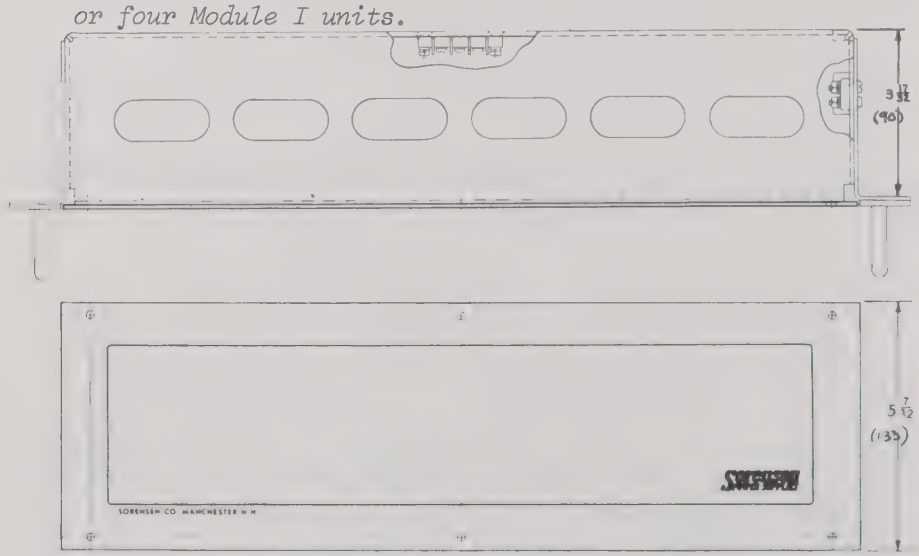
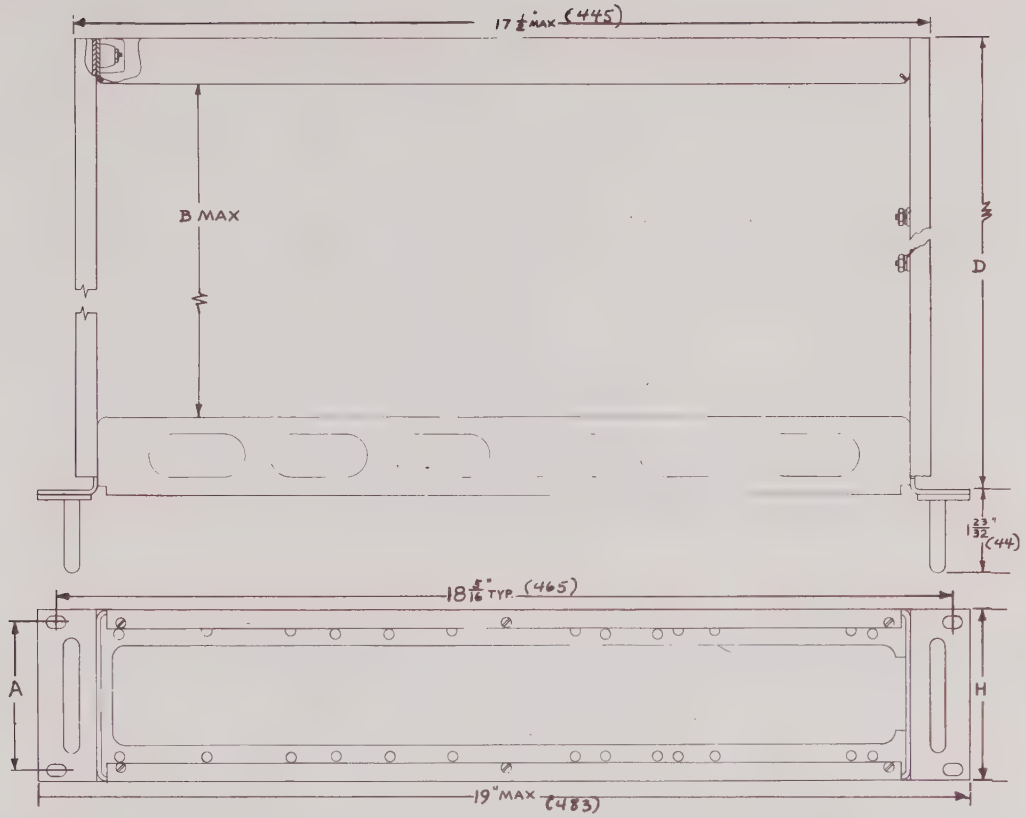


Figure 2-4 AC500 Rack Adapter (shown with unmetered panel)

NOTE

AC500 can accommodate four PTM-DUAL Modules.



MODEL	A	D	H
AC318	3 inches(76 mm)	17-1/2(445)	3-7/16(87)
AC320	3 inches(76 mm)	20 (508)	3-7/16(87)
AC518	2-1/4 inches(57 mm)	17-1/2(445)	5-3/16(132)
AC520	2-1/4 inches(57 mm)	20 (508)	5-3/16(132)

Figure 2-5 AC318, AC320, AC518, AC520 Rack Adapter

NOTE

These adapters will accommodate up to eight units.

SECTION III

OPERATING INSTRUCTIONS

3.1 GENERAL:

3.2 This section contains instructions on how to adapt the unit to, and operate it in, a number of varied applications. These include remote sensing, remote programming, and series and parallel operation.

CAUTION

The sensing and power circuits form a closed loop. Opening this loop, either by removing a terminal-board link or disconnecting a sensing or programming lead, will result in a high unit output and may damage the load or the supply.

3.3 CONTROLS:

3.4 QSA units are equipped with a single operating control, the Output Adjust potentiometer. This control is accessible through an aperture located in the nameplate end. Connected in series with the sensing network and across the output terminals, it is used to vary the unit output voltage.

3.5 PREOPERATION CONSIDERATIONS:

3.6 CURRENT/TEMPERATURE COMPENSATION: Figure 1-1 shows that the maximum safe output current is inversely proportional to ambient temperature beyond 40°C. Conversely, the value at which the current limit or foldback is set is relatively independent of temperature. This means that, although the safe current output may well decrease due to high ambients, the current limit/foldback remains at its factory-set value (approximately 125% I rated at 50°C). In effect, this nullifies the protection which current limit/foldback is designed to provide. It is therefore recommended that, if the unit is to be operated in ambients between 40 and 71°C, the current limit/foldback be reset.

3.7 COMPENSATION CALIBRATION: The value to which the current limit/foldback should be reset may be determined as follows: measure the temperature of the environment in which unit will operate. Turn to Figure 1-1 and find this point along the horizontal axis. Then extend a vertical line upward from the point until it intersects the curve. At the intersection, extend a horizontal line to the left until it meets the vertical axis. The intersection here is the percentage of derating. Multiply this percentage by the maximum output current at 50°C (Table 1-1). Take the product and multiply by 125%, or if a temperature-compensated setting is desired, by X%, which $X = 120 + \Delta T\ (0.2)$. (The ΔT (0.2) is a compensation factor for limit-circuit temperature sensitivity, where ΔT is the difference between 40°C and the actual ambients, and 0.2 is the temperature coefficient. The constant 120 compensates for the crossover and drift characteristics.)

3.8 Sample Calculation: For illustrative purposes, assume a Model QSA 10-2.2 is to be operated in an ambient of 62°C. From Figure 1-1, the derating percentage is found to be 80. The product of 0.80 and 2.2 is 1.76A. This is the derated output. Next, multiply 1.76A by 1.25. current obtained is 2.2A. For this example, 2.2A would be used as the new current-limit value.

3.9 CURRENT-LIMIT RESET (10-volt models only): To reset the current limit, proceed as follows:

a. Rotate Output Adjust fully clockwise.

b. Connect a dc ammeter (0.5% accuracy) across the output terminals. Select a 0-10A range on meter. The ammeter is to serve as an overload measuring instrument.

c. Remove side enclosure.

d. Apply nominal input power, and adjust potentiometer R6 on component board until ammeter indicates the compensated current-limit value.

e. Disconnect input power and test meter. Apply locking compound to R6, and remount enclosure.

3.10 CURRENT/FOLDBACK RESET (Model 5-6.4 only): To reset the current foldback, proceed as follows:

a. Remove the side enclosure to expose the component board.

b. Rotate foldback adjust potentiometer R6 fully clockwise.

c. Connect a voltmeter across the output terminals. Apply nominal input voltage and adjust the output voltage with output adjust control R18 to the lower limit of the unit's specified range. Alternatively, if the supply is to be used at a fixed voltage above the lower limit, set the output voltage to the fixed value.

d. Remove the input power and connect an ammeter and a variable load resistor in series across the output terminals.

e. Reapply the input power and adjust the load resistor so that the ammeter reads the foldback current calculated in paragraph 3.7.

f. Rotate potentiometer R6 slowly counterclockwise until both the output voltage and current just begin to drop.

g. Remove the input power, disconnect the test equipment, apply locking compound to R6, and replace the side enclosure.

3.11 LOCAL SENSING:

3.12 The unit is shipped ready for use in the local-sensing configuration. This means that the output is regulated at the output terminals, with no compensation for load-lead drops. If these drops are expected to be prohibitive, use the remote-sensing configuration as outlined in paragraph 3.14.

3.13 To operate the unit with local sensing, proceed as follows:

a. Connect a voltmeter across OUT (1 and 4) terminals.

b. Attach input leads to IN (6 and 7) terminals. Use GRD terminal (5) for input-system ground.

c. Apply nominal input power.

d. Rotate Output Adjust control until desired output voltage is indicated on voltmeter.

e. Remove input power, disconnect voltmeter and connect load leads to terminal 1 and 4. Do not remove or loosen any of the interconnecting links. Apply nominal input. Unit supplies highly regulated voltage to load.

WARNING

Do not touch enclosure while unit is operating under load. Surface temperature is high. If unit must be handled immediately after operation, wear heat-resistant gloves.

3.14 REMOTE SENSING:

3.15 If it is desirable to sense (regulate) unit output at the load rather than at the output terminals, remove links between the SENSE and OUT terminals. Using coaxial cable for the sensing leads, connect from SENSE terminals (2 and 3) to the load (see Figure 3-1), with the shield at the negative SENSE terminal (3). Put unit into operation per paragraph 3-13. The unit's transient response degenerates slightly in remote-sensing operation. If this is an undesirable feature, disconnect output capacitor C7 and reconnect it, or an identical capacitor, locally across the load. Rating of C7 may be determined from parts list in Section VI.

3.16 REMOTE PROGRAMMING:

3.17 RESISTANCE: The unit may be programmed to supply predetermined output voltages by inserting a calculated resistance into the programming circuit. In calculating the resistor's value, use the ratio of 100 ± 0.5 ohms/volt, i.e., for every volt of desired output between 0 and 10, about 100 ohms should be introduced into the programming circuit.

3.18 In selecting the resistor, make certain that it is a precision type with a low temperature coefficient (± 30 ppm/^{o}C). Programming current is 10 mA. Choose a resistor with a wattage rating at least 10 times that calculated.

3.19 To adapt unit for remote programming with remote sensing, place the precision resistor either across terminals 3 and 4 (labeled 1 in Figure 3-2), or in place of the jumper across component board terminal studs E5 and E6 (labeled 2). To gain access to component board, remove the side panel. For remote programming with local

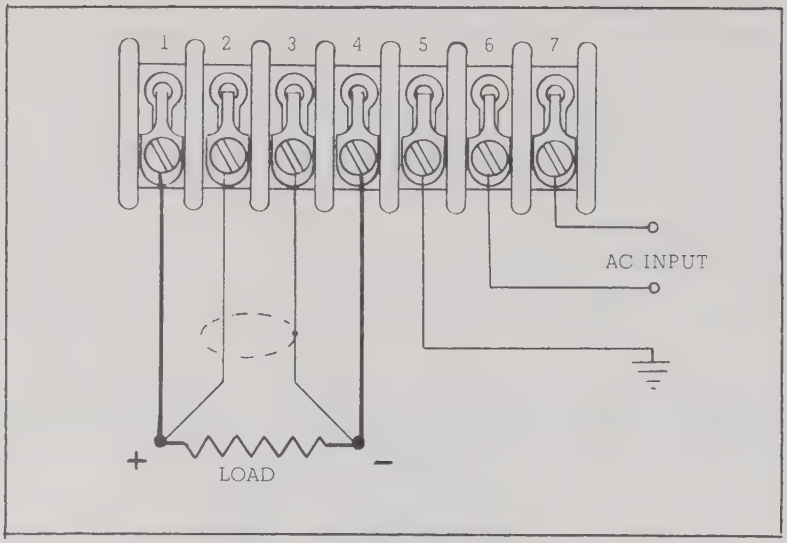


Figure 3-1 Remote Sensing

sensing, the precision resistor is substituted for the link between terminals 3 and 4 on the terminal board. Use twisted or shielded wire for connecting resistor leads. With the resistor in place, proceed as follows:

a. Turn Output Adjust control fully counterclockwise.

b. Apply nominal input power, and verify that the output voltage across terminals 1 and 4 is the desired value.

c. Disconnect input power, make load connections and reapply input. Programmed output is now supplied to load.

NOTE

To discontinue programming, remove input and precision resistor. If jumper or link was removed, reconnect it.

3.20 VOLTAGE: The unit may also be programmed to supply a constant or variable output by introducing a voltage signal into the programming circuit. The procedure is identical to that for resistance programming (paragraph 3-17), with this exception: instead of connecting a resistor across studs E5 and E6, connect the signal source. This source must be floating (not grounded and the signal should have a low-noise, low-ripple content. In addition, it must be capable of absorbing the 10 mA programming current. For voltage-signal programming, the programming sensitivity is 1 volt-per-volt, i.e., the signal source must provide one volt of signal for each volt of desired output. Do not use a signal greater than 10 V (7 V if programming 5-6.4).

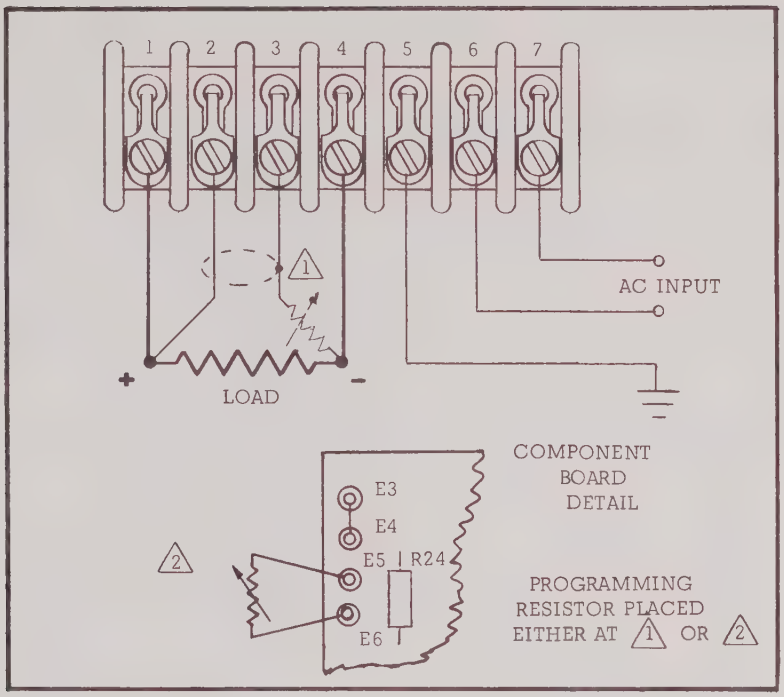


Figure 3-2 Remote Programming with Remote Sensing

3.21 SERIES OPERATION:

3.22 Combinations of QSA Models may be connected in series to provide a cumulative output voltage (Table 1-1). Maximum current output is limited to the output of the lowest rated supply. Total regulation is the sum of the regulations for all units.

3.23 If, in series operation, a unit fails, reverse voltage will appear across the failed unit's output terminals and consequently may damage the output capacitor. To clamp the reverse voltage to about 1 volt, connect a rectifier across each set of output terminals used in the system. Table 3-1 lists the rectifiers recommended for series operation.

3.24 To hook two units up in series, see Figure 3-3 and proceed as follows:

a. Remove links between the OUT (1 and 4) and SENSE (2 and 3) terminals on both units.

b. Connect an output lead from the positive OUT terminal (Unit 1) to positive side of load.

c. Run an output lead from the negative OUT terminal (Unit 2) to negative side of load.

d. Connect the negative OUT terminal (Unit 1) with positive OUT terminal (Unit 2).

e. Run sensing leads from positive SENSE terminal (Unit 1) and negative SENSE terminal (Unit 2) to load. Observe polarity.

f. Connect a sensing lead from the negative SENSE terminal (Unit 1) to positive OUT terminal (Unit 2). Next, using a sensing lead, connect the positive SENSE terminal (Unit 2) to the positive OUT terminal (Unit 2).

Table 3-1 Rectifier Recommendations, Series Operation

QSA MODEL	MANUFACTURER	MFR. PART NO.	SORENSEN PART NO.
*5-6.4	Westinghouse	409A 409AR	26-1096-1 26-1096-9
10-1.4	Solitron	HC 67	26-1027-3
10-2.2	Solitron	2A15	26-1002-1
10-3.7	Motorola	MR 1030A	26-1006-1

*Model 5-6.4 requires mounting forward and reverse polarity rectifiers with mica washers on a 2-1/4" square, 1/32" thick aluminum heatsink. Stud size of the rectifiers is 10-32 and mounting torque is 15-20 lb-in.

3.25 PARALLEL OPERATION:

3.26 Loads which draw currents higher than a single unit's rated output may be serviced by paralleling units. Parallel operation is based on the "master-slave" concept, i.e., the "master" unit amplifier supplies drive current to all "slave" units. (Slave unit amplifiers are disconnected during the paralleling procedure.)

3.27 The number of units which may be paralleled using the master-slave approach is dependent upon the amount of current available to drive the slave unit passing stages. This current is a variable from unit-to-unit, and depends upon dissimilarities, within acceptable tolerances, in component characteristics. The maximum number of units which may be paralleled is therefore a function of the master unit selected. Under the most unfavorable conditions, at least four units may be paralleled. If the tolerances in the master unit accumulate in the favorable direction, it is possible to parallel up to 15 units.

3.28 The following outlines the procedures for paralleling two units; however, the procedure need only be extended to parallel up to the maximum. Derate each unit to 90% of the maximum nominal output current. Maximum system output is the sum of the derated currents.

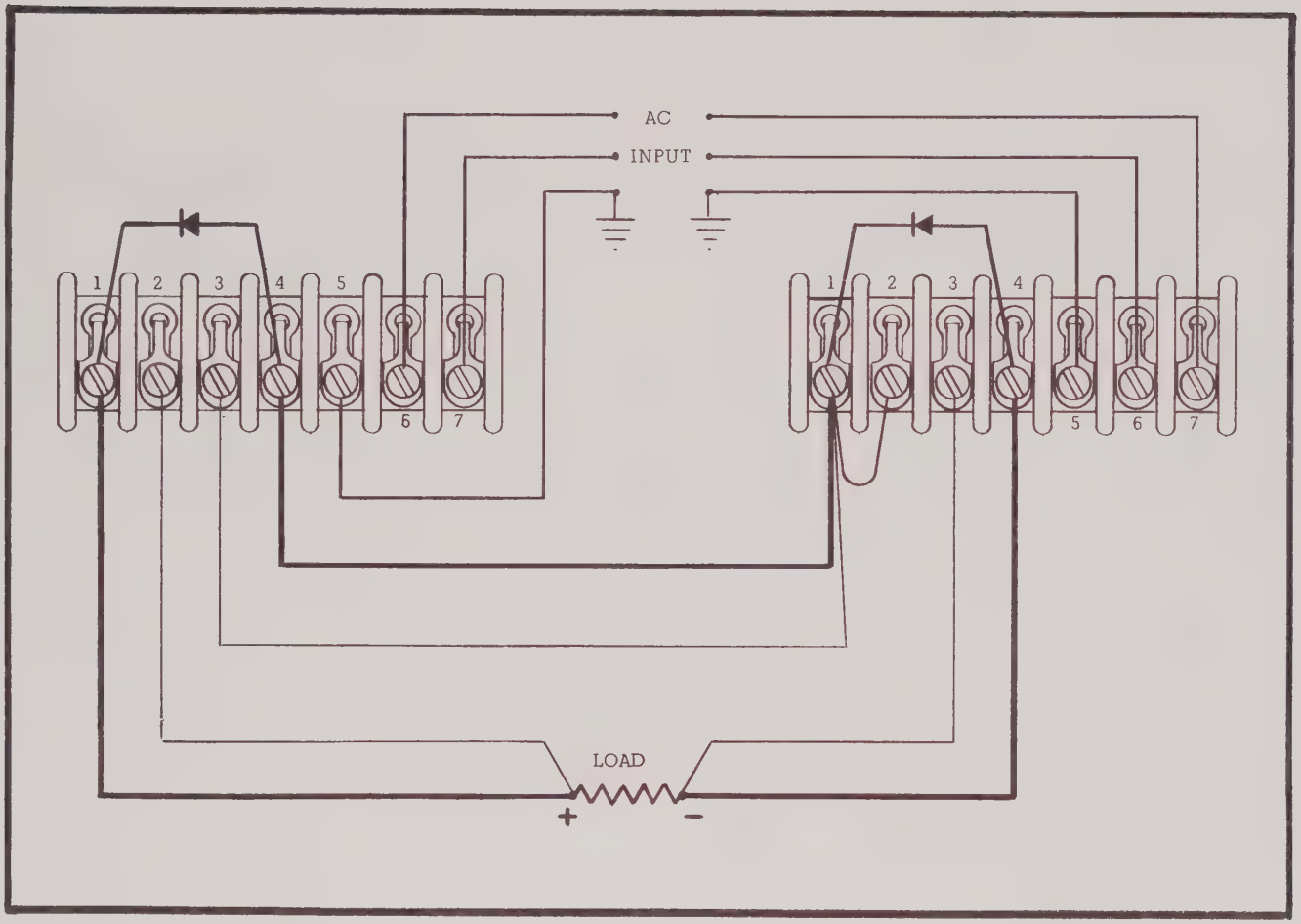


Figure 3-3 Series Operation

a. Apply input power to master unit, and adjust output voltage to desired value.

b. Remove input.

c. At internal component board of slave unit, disconnect or cut jumper across studs E1 and E2.

d. Interconnect stud E1 of this slave unit and stud E1 of the master unit. (See Figure 3-4.)

e. Connect load leads from each unit to load. Observe polarity.

f. If desired, remote sensing may be employed by connecting sensing leads from SENSE terminals of master unit to the load terminals, again observing polarity.

g. Apply nominal input power to all units.

NOTE

System output will drop to zero if there is a discontinuity in input power to any unit, master or slave.

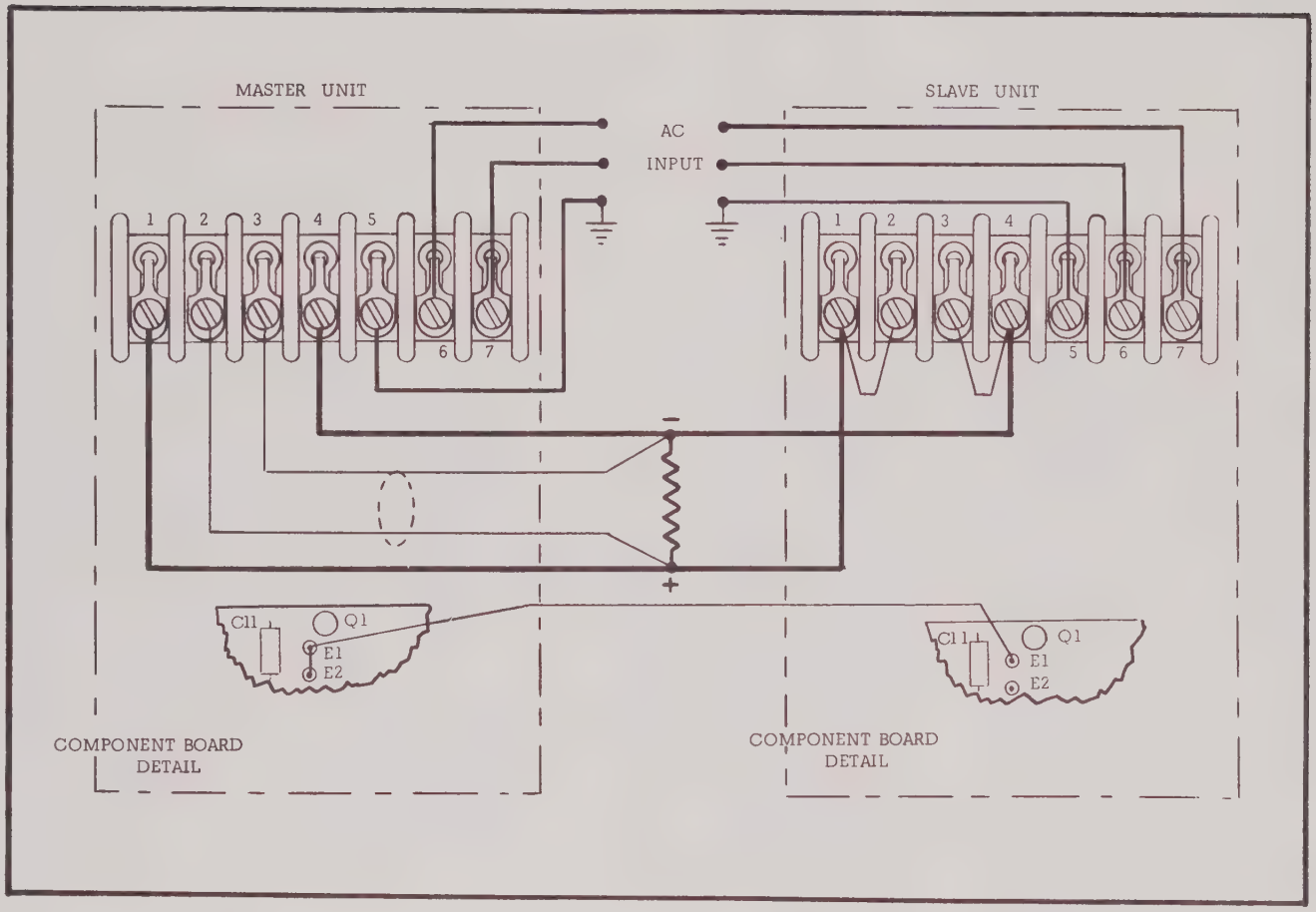


Figure 3-4 Parallel Operation

SECTION IV

PRINCIPLES OF OPERATION

4.1 GENERAL:

4.2 This section contains a description of the unit's operating principles, first in broad terms and then in more detail. Its function is to provide sufficient data which, when used in conjunction with the maintenance data and procedures outlined in Section V, will enable the user to logically and quickly isolate any unit malfunction.

4.3 PASSING-STAGE PRINCIPLE:

4.4 The QSA utilizes the series-passing-stage method of regulation. With this approach, a variable impedance absorbs the difference between the desired regulated output and filtered "brute-force" dc. The variable impedance, to simplify this discussion, is assumed to be a single transistor (actually two are connected in parallel in some QSA models). Automatic regulation occurs when an output-derived error signal, fed back through amplifiers, is applied to the passing stage. Figure 4-1 is an idealization, using input and output waveforms, of passing-stage operation.

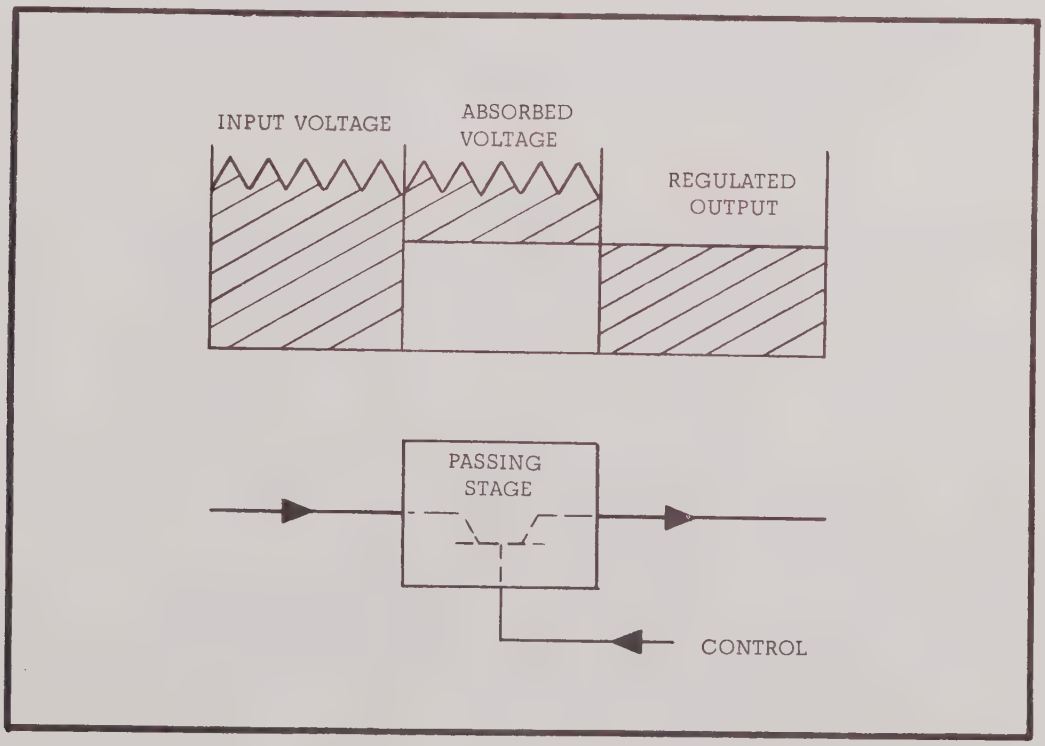


Figure 4-1 Series Passing Stage Principle

4.5 BLOCK DIAGRAM:

4.6 The following brief description discusses unit operating principles in a general manner. A more detailed treatment is presented in subsequent paragraphs. Refer to Figure 4-2: the input transformer accepts an ac input, steps down the voltage and applies it across a full-wave, center-tapped rectifier. Rectifier output is fed through a passing stage to the load. The passing stage acts to absorb difference between the rectifier and desired output voltage. The feedback loop to the passing stage includes a sensing and error amplifier which compares a sample of the unit's output against a fixed reference, provided by an internal reference power supply. Error signals resulting from the comparison are differentially amplified and fed to the driver. These signals are used to alter the impedance of the passing stage as a function of unit output. Short-circuit and overload protection is provided by the current-limit section.

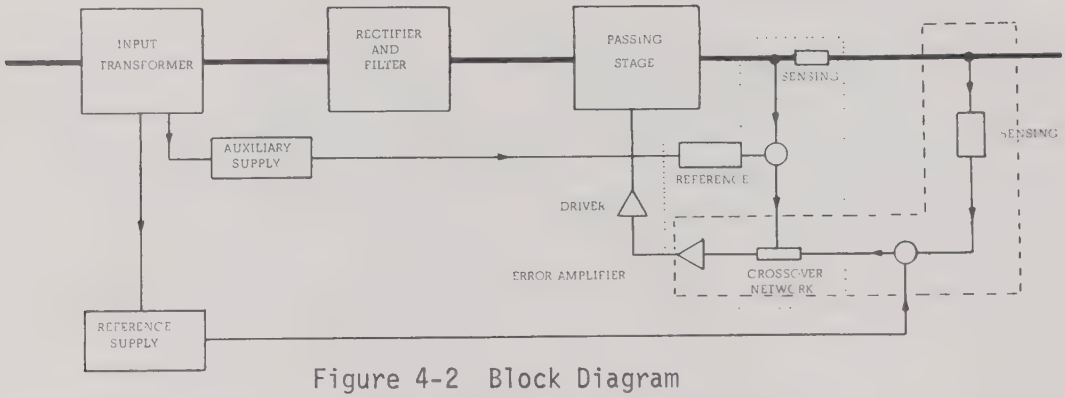


Figure 4-2 Block Diagram

4.7 DETAILED DISCUSSION:

4.8 REFERENCE POWER SUPPLY: The reference power supply provides 9 volts of highly stable, precise direct current as a reference for the sensing and error-amplification section. The supply derives its power from a full-wave, center-tapped rectifier (CR6-CR7), connected across a secondary winding of T1. Basic supply components include transistor Q5, two differential amplifiers Q6/Q7 and Q8/Q9, zener diode CR8 and potentiometer R15.

NOTE

For schematic locations of reference designations used throughout this section, see Figure 5-3.

4.9 Reference-supply output voltage is sensed across potentiometer R15, where a portion of the drop here is compared with a voltage reference developed by diode CR8. Resulting error signals are amplified and directed to the base of transistor Q5. Q5 acts as a variable impedance, increasing or decreasing the voltage drop across the stage as a function of the output voltage.

4.10 As an illustration of circuit operation, assume that an increase in reference-supply output voltage is sensed across potentiometer R15. A portion of the sensed voltage is compared with the constant voltage developed across CR8. The resulting error signal forces Q9 into higher conduction. The current through Q9 increases, while that through Q8 decreases. (Resistor R16 acts as a current generator, pulling an approximately constant current that is the sum of the operating currents of Q8 and Q9.) Increasing current through Q9 brings about a decrease in drive current on the base of Q6. Operating current through Q6 drops, decreasing the drive to Q5. As a result, Q5 conducts less (impedance increases) and the voltage across R15 is regulated to the precise 9-volt output.

4.11 SENSING AND ERROR-AMPLIFIER SECTION: In this section, a comparison is made between the precise output from the previously described reference supply and a portion of the unit output voltage. Resulting error signals are differentially amplified and fed to the passing-stage section. Main components include output-adjust potentiometer R18, resistor R25, and differential amplifiers (Q12/Q13 and Q10/Q11).

4.12 As an illustrative example of circuit operation, assume that the output voltage starts to rise. The voltage across R18 increases and therefore the base of Q12 becomes more negative with respect to the base of Q13. The operating current through Q12 decreases, and the current in Q13 increases. (The increase results because the sum of the operating currents of Q12 and Q13 is held approximately constant by R24.)

4.13 DRIVERS AND PASSING STAGE: The drivers and passing stage are composed basically of two amplifiers (drivers) Q1 and Q3, and transistor Q2, connected in the psoitive output leg. Driver Q1 accepts a signal from differential amplifier (Q10-Q11), amplifies and then feeds it to the base of Q3. The signal is again amplified and directed to the base of Q2 where it determines Q2's conduction level, causing an increase or decrease in the absorbed voltage as a function of unit output.

4.14 CURRENT-LIMIT SECTION (10-Volt Models): The current-limit section operates to provide unit overload protection. If output current begins to increase above a preset value (determined by potentiometer R6), unit output voltage is rapidly decreased while the output current is held approximately constant. Main components include reference diode CR5, resistors R5/R6 and transistor Q4.

4.15 The section functions as follows: under normal conditions, transistor Q4 is nonconducting because of insufficient base-emitter voltage. However, as output current attempts to rise above the limiting value, the drop across R7 increases, as does the sum of the voltages across R6 and Q4 base-emitter. The voltage across R6 is held constant by CR5, and as a result, only Q4's base-emitter voltage increases. Q4 is then driven into conduction and draws current from differential amplifier Q10/Q11. As may be recalled from paragraph 4.12, this amplifier supplied the signal current to the drivers and passing stage, and it is this current which is rerouted. As a result, signal current to the drivers and passing stage is greatly diminished, and transistor Q2 approaches cutoff. The output voltage drops as more voltage is absorbed by the passing stage and then stabilizes when the load conduction is satisfied.

4.16 CURRENT-FOLDBACK SECTION (Model 5-6.4): The current-foldback section provides overload protection in the Model 5-6.4 power supply. While its purpose is the same as the current-limit circuit in the 10-volt supplies, it operates in somewhat different manner. When the load on the Model 5-6.4 exceeds a safe maximum, both the output current and the output voltage of the supply decrease in proportion to the excess of load.

4.17 Detailed circuit operation is almost identical to the operation of the current-limit circuit used in the 10-volt models - the only difference is the rearrangement of the circuit to return resistor R5 to the collector of Q4. This provides a negative feedback at the base of Q4, which tends to shift the operating point of Q4 by changing the base bias with increasing overload. The combined effect of the change in base bias and the change in voltage drop across R7A with overload cause both output current and output voltage to decrease.

4.18 REVERSE-BIAS SECTION: The reverse-bias section functions (1) during "load-off" transients to improve the response time by rapidly cutting off the passing stage and (2) to absorb "thermal effect" current generated at high junction temperature. The section is made up of a full-wave, center-tapped rectifier CR2/CR3, capacitor C4, and resistors R1, R2 and R3.

SECTION V
MAINTENANCE

5.1 GENERAL:

5.2 This section provides troubleshooting data, periodic servicing, and calibration and performance-testing procedures. The troubleshooting data should be used in conjunction with the schematic diagram (Figure 5-3) which tabulates voltage check points, Section IV which outlines the principles of operation, and Figures 5-1 and 5-2 which physically locate the parts appearing on the schematic. Any questions pertaining to repair should be directed to the nearest Sorensen representative (a list is included with the unit) or to the Service Department, Sorensen Company, 676 Island Pond Road, Manchester, New Hampshire, 03103. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from the Sorensen Service Department must be obtained first. Sorensen Company will not assume responsibility for units returned without prior authorization.

5.3 PERIODIC SERVICING:

5.4 The QSA Models require no periodic servicing. However, it is recommended that whenever a unit is taken off the line, the enclosure be inspected and cleaned of any accumulations of dust or other debris which could impede natural air flow through unit.

5.5 TROUBLESHOOTING:

5.6 Table 5-1 lists a number of malfunction symptoms and their probable causes. The table covers symptoms which are attributed to a single component failure only. This should not be interpreted to mean that there could not be other causes for the tabulated symptoms. Multiple failures, for instance, may give identical indications. Footnotes in the table indicate which components may be damaged due to a "chain-reaction" effect. If any amplifier components are replaced, unit may require calibration. Refer to paragraph 5.7.

5.7 CALIBRATION:

5.8 To calibrate a QSA supply, proceed as follows (open text applies to 10-volt models, values in parentheses apply to Model 5-6.4):

a. Remove side enclosure.

b. Rotate Output Adjust R18 fully counterclockwise (shaft is accessible through aperture in the nameplate.

c. Remove nameplate, and turn bridge-voltage control R15 to center of rotation range (shaft is located directly above R18 when unit is in the normal position, i.e., with markings at terminal board right-side up).

Table 5-1 Troubleshooting Data

SYMPTOM	PROBABLE CAUSE
No Output	a. No input. b. User-supplied fuse blown (check for shorted rectifier CR1, CR2, CR3, CR4, CR6 or CR7 (1) or shorted transformer winding).
High Output	a. In reference supply, Q9, Q7 or CR8 open. Q8, Q6 or Q5 shorted. Defective R15. b. Q1, Q3 or Q2 shorted (2). C. In sensing and error-amplification section, Q10 or Q12 shorted, or Q11 or Q13 open.
Low or Negative Output	a. In reference supply, Q9, Q7 or CR8 shorted. Q8, Q6 or Q5 open. b. Q1 or Q3 open. c. In sensing and error-amplification section, Q10 or Q12 open, or Q11 or Q13 shorted. d. In current-limit section, Q4 or CR5 (3) shorted.
Output Ripple Degenerates	CR1 or CR4 open.
Transient Response Degenerates	CR2 or CR3 open.

(1) Complementary rectifier and transformer may be damaged.
(2) When replacing Q2, apply thermal junction compound to underside of transistor. Use Thermacote, Thermalloy Co., Dallas, Texas, or an equivalent.
(3) 10-volt models only.

5.8 Calibration (Cont'd)

d. Rotate current-limit control R6, located on component board, fully clockwise.

e. Remove jumper from across terminal studs E5 and E6 on component board, and then connect a precision-resistor box across studs. Set box resistance to exactly 1000 (700) ohms.

f. Connect a sensitive 0-15 (0-10) Vdc voltmeter across the OUT terminals on terminal board. At no load, apply nominal input to IN terminals.

g. Rotate bridge-voltage control R15 to obtain a voltmeter indication of 10 ±0.05 (7 ±0.05) volts.

(cont'd)

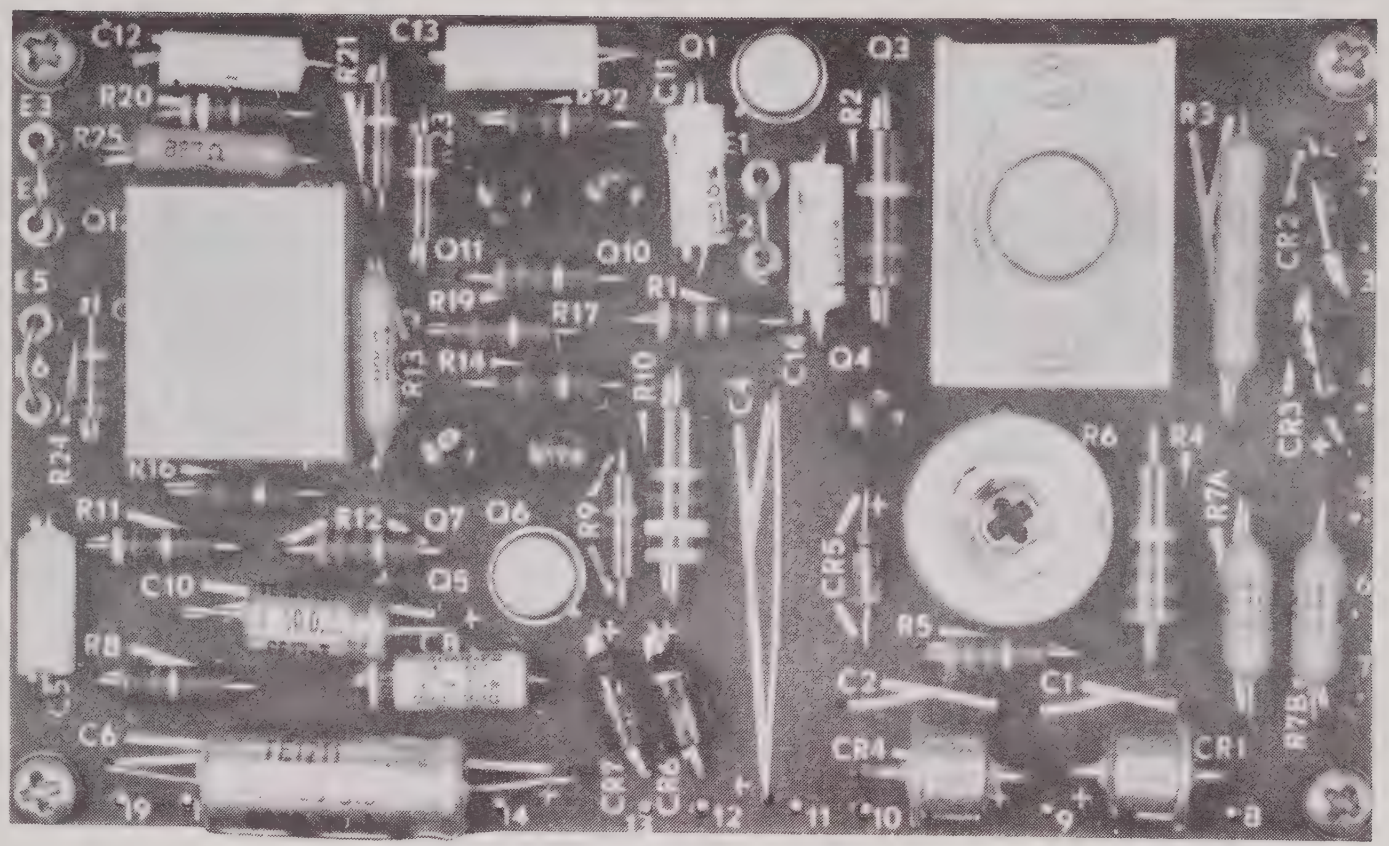


Figure 5-1 Typical Component Board

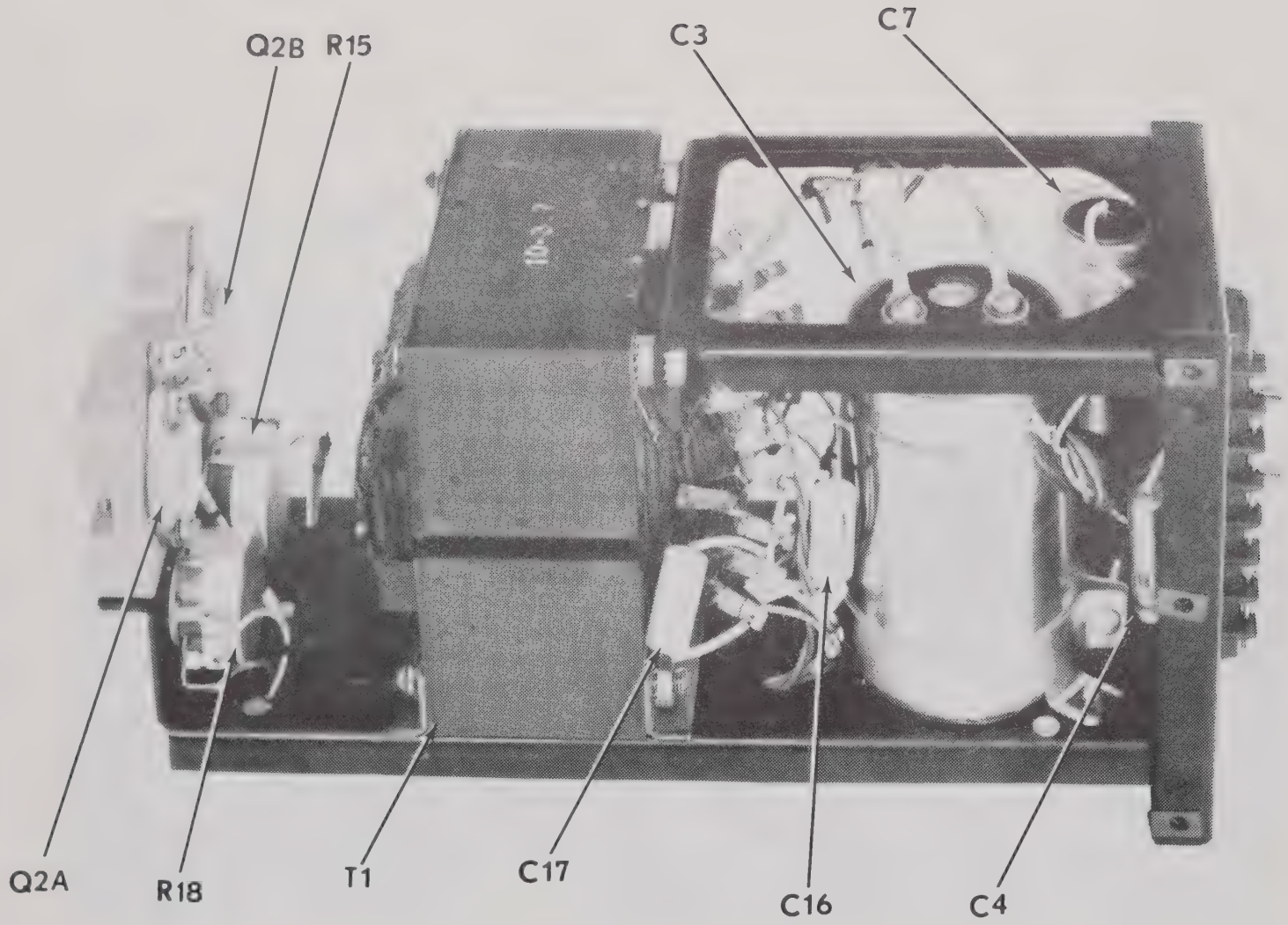
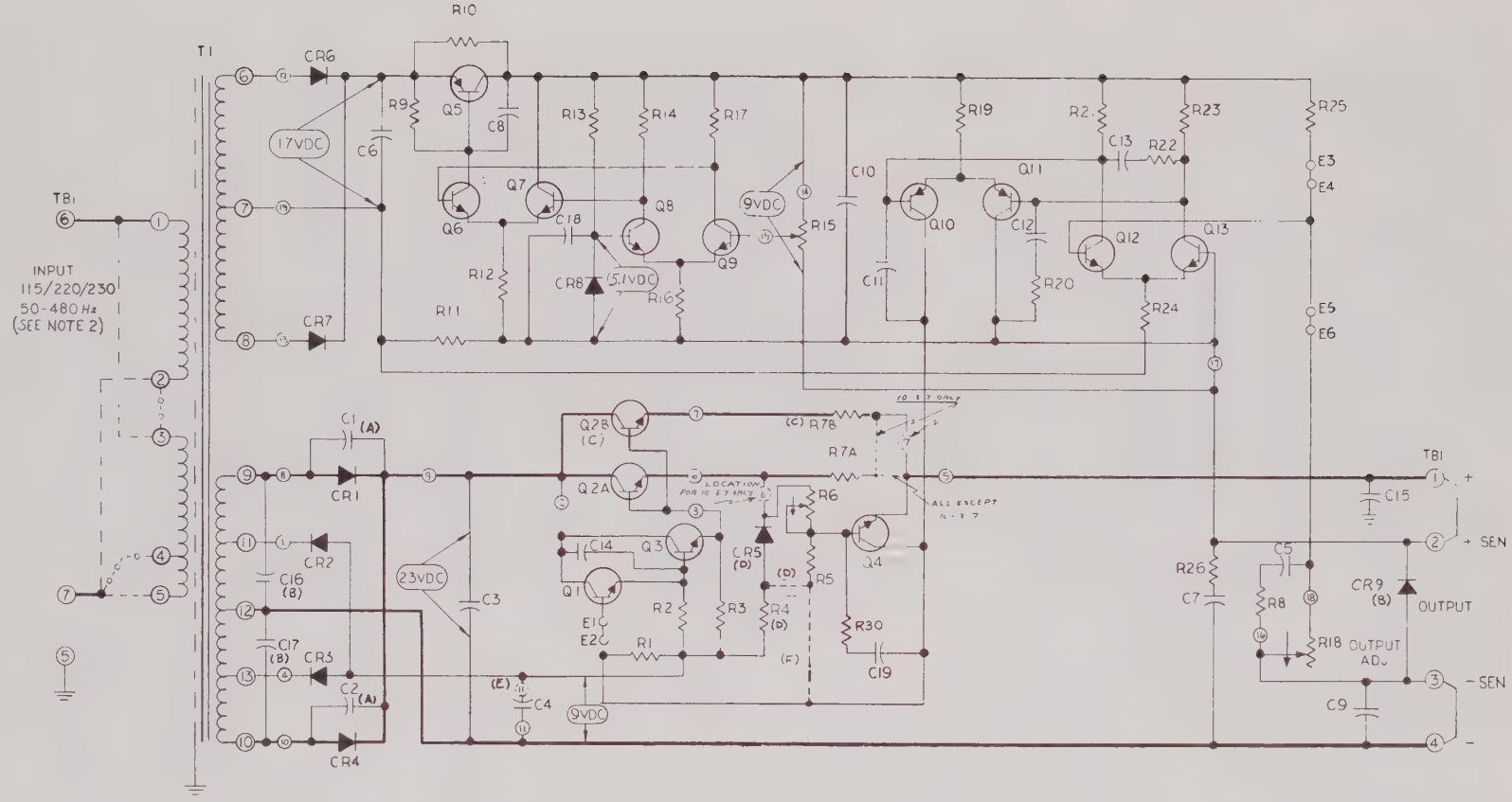


Figure 5-2 Partial Disassembly (typical)



C200-3960 Rev F

(A) Used on 5-6.4/10-1.4 only.
(B) Used on 10-2.2/10-3.7 only.
(C) Not used on 10-1.4.
(D) Not used on 5-6.4.
(E) Terminal used here on 5-6.4/10-3.7 only.
(F) Connection used on 5-6.4 only.

NOTES:

1) All voltages measured at nominal input, nominal output, no load.
2) See Figure 2-1 for input connections.

Figure 5-3 Schematic Diagram

h. Remove input power, disconnect resistor box and reconnect jumper across studs E5 and E6. Reconnect input.

i. At no load and nominal line, turn Output Adjust R18 from stop-to-stop. Test voltmeter should indicate a range of 0 to 10 (3-7) V.

j. With output set at 10 (7) volts, disconnect input.

k. Using load leads, connect a 10 Adc meter across the OUT terminals.

l. Rotate current-limit control R6 fully counterclockwise.

m. Apply nominal input and adjust R6 to obtain an indication of 1.85-1.95 A (QSA 10-1.4), 2.9-3.0 A (QSA 10-2.2), 4.9-5.1 A (QSA 10-3.7), or 8.7-8.9 A (QSA 5-6.4) on test ammeter.

n. Remove input. Disconnect test meters and resistance box. Apply locking compound to potentiometers R6 and R15.

o. Replace nameplate and side enclosure.

5.9 PERFORMANCE TESTING:

5.10 OUTPUT RIPPLE: To measure output ripple, proceed as follows (open text applies to 10-volt models, values in parentheses apply to Model 5-6.4):

a. Connect a test set-up as shown in Figure 5-4. Set oscilloscope for 0.5 mV/cm vertical and 10 ms/cm horizontal. (Oscilloscope should have at least a 30 MHz bandwidth.) Select a 150-V range for ac input voltmeter. Choose a 0.5 mV range for RMS meter and a 5 (10) A range for dc ammeter. Use a resistive load with a working current rating of at least 5 (10) A. Use the differential voltmeter as a VTVM. Select a 15 (10) volt range.

b. With no load, apply a 115 Vac, 60 Hz input, and adjust output to 10 (5) volts.

c. Apply full load and observe oscilloscope and RMS voltmeter. Voltmeter should indicate no more than 0.3 mV; oscilloscope should display a peak-to-peak voltage no greater than 3 mV.

d. If desired, check regulation per paragraph 5.11.

5.11 REGULATION: To measure unit's output regulation, proceed as follows (open text applied to 10-volt models, value in parentheses applies to Model 5-6.4):

a. Connect unit to test set-up shown in Figure 5-4. The oscilloscope and RMS voltmeter are not necessary. Use the voltmeter in the differential mode. Select an internal voltage equal to 10 (5) volts, and set null sensitivity to the 10 mV range.

b. Apply a 115 Vac, 60 Hz input, and adjust output voltage to obtain a null indication on voltmeter.

c. With ac voltmeter indicating 115 Vac, increase load on unit until dc ammeter reads 7 A (QSA 5-6.4), 1.54 A (QSA 10-1.4), 2.4 A (QSA 10-2.2) or 4.0 A (QSA 10-3.7). Record the deviation from voltmeter null position.

d. Adjust voltmeter internal voltage to regain the null position. Then, with full load on unit, vary unit input voltage at 60 Hz from 105 to 125 Vac. Note the deviation.

e. Sum the deviations recorded in steps c and d. The total should be less than 1 mV (not greater than 0.5 mV).

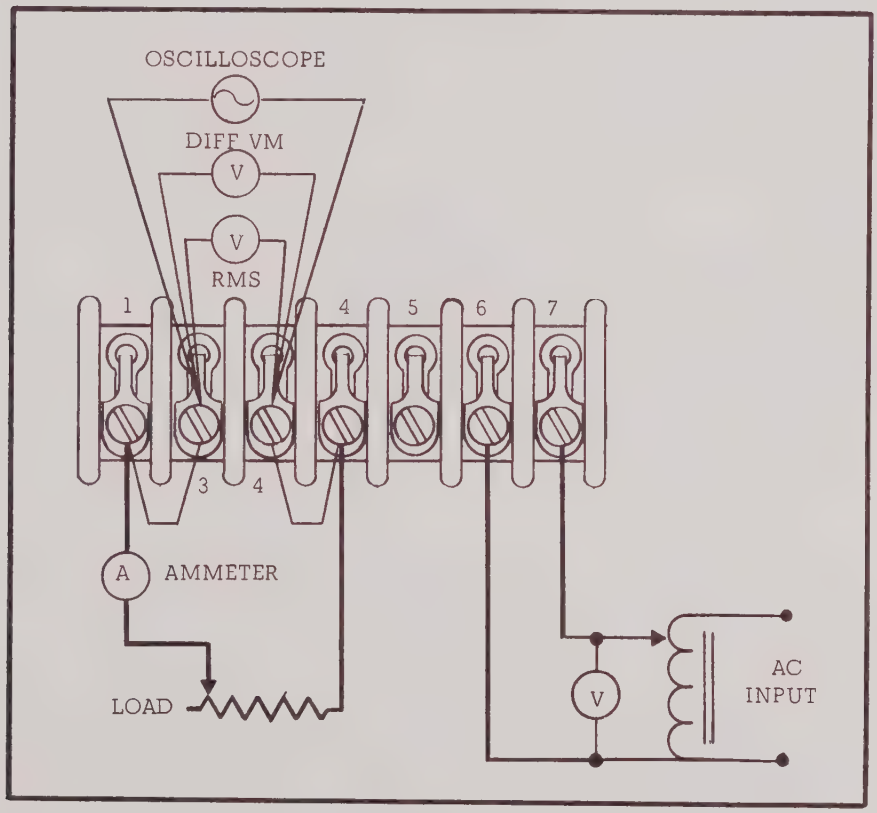


Figure 5-4 Performance Test Setup

5.12 HI-POT TEST PROCEDURE: It is recommended that this test be performed only if a component has been repaired or replaced which could affect the dielectric capability of the unit.

Note: If unit has been in service for an extended period, it should first be cleaned of dust or any other accumulations.

A. Test Limits:

Input - 1300 Vdc
Output - 200 Vdc

B. Test Equipment Required:

Hi-Pot Tester - Electrospace
Model 650 "Megpot" or equivalent.

Jumpers/Clip Leads as required.

C. Equipment Set-up:

1. Isolate unit input line cord from power source and chassis.

2. Connect input terminals TB1-6 and -7 together.

3. Connect all output terminals together.

4. Set hi-pot tester switch to ON.

D. Input Test:

1. Connect the unit output terminals to chassis ground.

2. Set the trip current control on the hi-pot tester to 100 microamperes, and voltage control to 0.

3. Connect the hi-pot tester from the input terminals to chassis ground.

4. Gradually increase the hi-pot voltage from 0 volts to input test limit (paragraph A. preceding).

5. Hold maximum specified level for at least five seconds. No breakdown shall occur during test.

6. Decrease hi-pot voltage to 0 volts.

CAUTION

Charged capacitors must not be shorted to ground to remove the charge. This voltage must be discharged slowly thru a 47K, 2W resistor. Failure to follow this instruction can result in damage to semiconductors resulting in immediate or subsequent unit failure.

7. Disconnect hi-pot leads from power supply input terminals.

8. Remove output terminal ground.

E. Output Test:

1. Connect the unit input terminals to chassis ground.

2. Set the trip current control on the hi-pot tester to 100 microamperes, and output voltage control to 0 volts.

3. Connect the hi-pot tester from the output terminals to chassis ground.

4. Gradually increase the hi-pot voltage from 0 volts to output test limit (paragraph A. preceding).

5. Hold maximum specified level for at least five seconds. No breakdown shall occur during test.

6. Decrease hi-pot voltage to 0 volts.

CAUTION

Charged capacitors must not be shorted to ground to remove the charge. This voltage must be discharged slowly thru a 47K, 2W resistor. Failure to follow this instruction can result in damage to semiconductors resulting in immediate or subsequent unit failure.

7. Disconnect hi-pot leads from power supply output.

8. Remove input terminal ground.

9. Remove input and output terminal jumpers.

Section VI
Replacement Parts List

6.1 INTRODUCTION

This section provides replacement parts list for the QSA power supplies. The lists are keyed to the schematic diagram (Figure 5-3) and the parts locating photographs (Figures 5-1 and 5-2). Table 6-1 lists parts for the covered QSA models.

6.2 TABLE HEADINGS DEFINED

6.2.1 Circuit Symbol

This is an alpha-numeric identification of the component as called out on the unit drawings.

6.2.2 Sorensen Part Number

This number should be used when ordering parts direct from:

Sorensen Company
Replacement Parts Dept.
676 Island Pond Road
Manchester, N. H. 03103

6.2.3 Manufacturer, Type

This is the basic group or series under which the part is listed by a manufacturer. The coded identification of manufacturers is listed below, alphabetically.

Mfr. Code	Manufacturer
AB	Allen Bradley Co.
AC	Acushnet Capacitor Co.
AER	Aerovox Corp.
BNS	Bourns, Incorporated
BUS	Bussman Mfg./Div. McGraw-Edison
CD	Cornell-Dublier Corp.
CG	Corning Glass Works
CL	Clarostat Corp.
CTS	CTS Corporation
ELA	Electra/Midland
EMC	Electromotive Mfg. Co.
GE	General Electric Co.
GI	General Illuminating Co.
IND	Industrial Devices
IR	International Rectifier
ITT	International Telephone
KEM	Kemet Div. Union Carbide Corp.
KC	Keystone Carbon
LF	Littelfuse Corporation
MA	Motorola
MAL	P. R. Mallory Co.
MG	Magnetics, Inc.
NS	National Semiconductor
RAM	RAM Electronics
RCA	RCA Corporation
RCL	RCL Electronics
RDM	Radio Material Co./Div. P.R. Mallory
SAN	Sangamo Electric
SE	Seacor, Incorporated
SEM	Semtech Corporation
SIG	Signetics Corp.
SP	Sprague Electric
SR	Sorensen Company
ST	Solitron Devices
STM	STM Corporation
TEL	Teledyne Semiconductor Division
TRW	TRW
UC	Union Carbide
WH	Westinghouse Semiconductor Division
WL	Ward Leonard

TABLE 6-1
REPLACEMENT PARTS LIST

CIRCUIT SYMBOL	OSA SERIES 5-6.4	10-1.4	10-2.2	10-3.7	DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER, TYPE
					Capacitors (uf unless noted)		
C1	X				2.2, 100V	587626-12	SE, 105
		X			0.0047, 200V	24-2409-5	AC, V146XR
			X	X	Not used		
C2	X				2.2, 100V	587626-12	SE, 105
		X			0.0047, 200V	24-2409-5	AC, V146XR
			X	X	Not used		
C3	X				17, 20V	24-2459-3	SP, 32D
		X			1.4, 25V	24-2452-5	SP, 34D
			X		3.4, 25V	24-2544-2	SP, 32D
				X	6.7, 30V	24-2444-4	SAN, 500
C4	X	X	X	X	200, 15V	24-2278-17	SP
C5	X	X	X	X	0.0047, 200V	24-2409-5	AC, V146XR
C6				X	100	235-7404P8	CD, 7E1211
C7	X			X	2, 20V	24-2455-1	SP, 34D
		X			650, 25V	24-2452-2	SP, 34D
			X		1, 25V	24-2452-4	SP, 34D
C8	X				0.01, 250V	24-2015-1	SE, MMK
		X	X	X	0.01, 200V	24-2409-7	AC, V146XR
C9	X	X	X	X	0.022, 200V	24-2409-9	AC, V146XR
C10	X	X	X	X	4, 50V	235-7404P38	CD, TE1302-1
C11	X	X	X	X	0.0022, 200V	24-2409-3	AC, V146XR
C12	X	X	X	X	0.0068, 200V	24-2409-6	AC, V146XR
C13	X	X	X	X	0.022, 200V	24-2409-9	AC, V146XR
C14	X	X	X	X	0.015, 200V	24-2409-8	AC, V146XR
C15	X	X	X	X	0.015, 200V	24-2409-8	AC, V146XR
C16	X	X			Not Used		
			X	X	0.15, 200V	24-2409-14	AC, V146XR
C17	X	X			Not used		
			X	X	0.15, 200V	24-2409-14	AC, V146XR
C18	X	X	X	X	15, 12V	235-7404P30	CD, TE1129
C19	X				0.002, 500V	24-2023	CEN, DD-202
		X	X	X	0.01, 50V	235-7361P2	CEN, DDM
					Diodes		
CR1	X				1N1200A	587393-1	WH
		X			RG-118	587565-1	SEM
			X	X	1N4720	26-1006-2	MA
CR2	X				S11	587565-1	SEM
		X	X	X	S11	587565-1	SEM
CR3	X				S11	587565-1	SEM
		X	X	X	S11	587565-1	SEM
CR4	X				1N1200A	587393-1	WH
		X			RG-118	587565-1	SEM
			X	X	1N4720	26-1006-2	MA
CR5	X				Not used		
		X	X	X	1N750A	26-211	MA
CR6	X				S11	587565-1	SEM
		X	X	X	S11	587565-1	SEM
CR7	X				S11	587565-1	SEM
		X	X	X	S11	587565-1	SEM
CR8	X	X	X	X	1N750A	26-211	MA
CR9	X	X			Not used		
			X	X	1N4720	26-1006-2	MA
					Transistors		
Q1	X				2N697	18-115	RCA
		X	X	X	RT-9343	18-145	RAY
Q2a	X	X	X	X	2N3055	18-115	RCA
Q2b	X		X	X	2N3055	18-115	RCA
		X			Not used		
Q3	X	X	X	X	40312	18-142	RCA

TABLE 6-1
REPLACEMENT PARTS LIST

CIRCUIT SYMBOL	QSA SERIES 5-6.4	10-1.4	10-2.2	10-3.7	DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER, TYPE
					Transistors (Cont'd.)		
Q4	X				FSC 3641	18-144	FC
		X	X	X	2N697	18-115	RCA
Q5	X	X	X	X	2N2905A	386-7249P40	GE
Q6	X	X	X	X	FSC 3641	18-144	FC
Q7	X	X	X	X	FSC 3641	18-144	FC
Q8	X	X	X	X	FSC 3641	18-144	FC
Q9	X	X	X	X	FSC 3641	18-144	FC
Q10	X	X	X	X	2N3638	18-143	FC
Q11	X	X	X	X	2N3638	18-143	FC
Q12	X	X	X	X	FSC 3641	18-144	FC
Q13	X	X	X	X	FSC 3641	18-144	FC
					Resistors (ohms, ½w, +10% unless noted)		
R1	X	X	X	X	47K	280-1145P134	AB, EB
R2	X	X	X	X	1.8K, 1W	280-1180P83	AB, 032
R3	X	X	X	X	180, 5W, 5%	27-1521	WL, 5XM
R4	X				Not used		
		X	X	X	680, 1W	280-1180P68	AB, 032
R5	X				1.8K	280-1145P83	AB, EB
		X	X	X	680	280-1145P68	AB, EB
R6	X	X	X	X	400, 3W, 20% Variable	29-489	CTS, HC110
R7a	X				0.27, 10W, 5%	27-1530	IRC, PW-10
		X			0.64, 3W	27-1517	WL, 3X
			X		1, 3W	27-397-25	WL, 3X
				X	0.47, 5W	586054-9	TL, EL5
R7b	X				0.27, 10W, 5%	27-1530	IRC, PC-10
		X			Not used		
			X		1, 3W	27-397-25	WL, 3X
				X	0.47, 5W	586054-9	TL, EL5
R8	X	X	X	X	120	280-1145P41	AB, EB
R9	X	X	X	X	220	280-1145P50	AB, EB
R10	X	X	X	X	390, 1W	280-1180P59	AB, 032
R11	X	X	X	X	47	280-1145P26	AB, EB
R12	X	X	X	X	820	280-1145P71	AB, EB
R13	X	X	X	X	221, 1%	28-1188	IRC, CEC-TO
R14	X	X	X	X	1.8K	280-1145P83	AB, EB
R15	X	X	X	X	2K, 4W, Variable	29-486	CL, 45
R16	X	X	X	X	1.8K	280-1145P83	AB, EB
R17	X	X	X	X	1.8K	280-1145P83	AB, EB
R18	X				750, 4W, Variable	29-545	CL
		X	X	X	1.1K, 4W, Variable	29-488	CL, 45
R19	X	X	X	X	680	280-1145P68	AB, EB
R20	X	X	X	X	390	280-1145P59	AB, EB
R21	X	X	X	X	2.7K	280-1145P89	AB, EB
R22	X	X	X	X	120	280-1145P41	AB, EB
R23	X	X	X	X	2.7K	280-1145P89	AB, EB
R24	X	X	X	X	680	280-1145P68	AB, EB
R25	X	X	X	X	887, 1%	28-1216	IRC, CEC T2
R26	X				0.4	190-3907	SR
		X	X	X	0.2	190-3636	SR
R30	X	X	X	X	1K, 1/4W	280-1171P74	AB, CB

TABLE 6-1
REPLACEMENT PARTS LIST

CIRCUIT SYMBOL	OSA SERIES 5-6.4	OSA SERIES 10-1.4	OSA SERIES 10-2.2	OSA SERIES 10-3.7	DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER, TYPE
TB1	X	X	X	X	Terminal Board	43-082-2	BEAU, 7-140Y
T1	X				Transformer	126-3045	SR
		X			Transformer	126-2889	SR
			X		Transformer	126-2890	SR
				X	Transformer	126-2891	SR
					Miscellaneous		
	X			X	Case	73-1649	SR
		X			Case	73-1597	SR
			X		Case	73-1632	SR
	X				Cover, End	73-1648	SR
		X			Cover, End	73-1596	SR
			X		Cover, End	73-2177	SR
				X	Cover, End	73-1631-2	SR
	X				Cover, Side	73-1649	SR
		X	X		Cover, Side	73-1595	SR
				X	Cover, Side	73-1648	SR
	X				Schematic	200-4128	SR
		X	X	X	Schematic	200-3960	SR

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